SYNCHRONIZED WIRELESS COMMUNICATIONS SYSTEM

FIELD OF THE INVENTION

The invention pertains to wireless communications systems. More particularly, the invention pertains to such systems which also minimize energy requirements between synchronization signals.

BACKGROUND

Electrical units which can communicate wirelessly can often be readily installed in circumstances where it is either inconvenient or undesirable to install a wired network. In other circumstances, it is useful and convenient to use both wired and wireless devices in the same system, depending on specific needs.

Wireless devices are found, for example, in the form of wireless hazardous condition detectors such as smoke detectors, fire detectors, flame detectors, thermal detectors, or gas detectors. Still other wireless units have been implemented in the form of condition detectors, such as position detectors, motion detectors, passive infrared detectors and the like. Other types of wireless electrical units implement a desired function, such as opening or closing doors, locking or unlocking doors, controlling motors, controlling relays, solenoids or the like, all without limitation.

One of the known problems associated with using wireless electrical units has been the power consumed during normal operation of the device. Where the wireless unit can be coupled to an exterior source of energy, such as utility supplied power, electrical energy requirements to operate the respective unit or units can be readily met. In other types of installations where the units must be battery powered, energy consumption can become a serious limitation.

One of the reasons that energy consumption in known units is problematic is that the wireless receiver in the respective device must be continuously "on", and drawing electrical power so that incoming signals can be received and sensed at the unit.

Fire detectors that use RF communication methods have typically incorporated transmitters only due to the reduction of battery life that results when receivers are implemented in the detectors. The receivers are generally ON all the time because they are asynchronous to the other devices in the system.

There is a continuing, on-going need for wireless electrical units with reduced or minimal current requirements. Preferably, such units could be implemented to carry out the known types of functions associated with such units while at the same time, reducing unit energy requirements. Preferably, such units would be installable in both new and existing systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a system in accordance with the invention;

FIG. 1A is a block diagram of an electrical unit module in the system of FIG. 1;

FIG. 2 is a timing diagram indicative of operation of the system of FIG. 1;

FIG. 3 illustrates another method of device arbitration; and

FIG. 4 illustrates a method of device discrimination.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

While this invention is susceptible of an embodiment in many different forms, there are shown in the drawing and will be described herein in detail specific embodiments thereof with the understanding that the present disclosure is to be considered as an exemplification of the principals of the invention. It is not intended to limit the invention to the specific illustrated embodiments.

A method that embodies the invention uses both transmitters and receivers in detectors and still maintains a long battery life by synchronizing the detector as described below.

In one embodiment of this invention, a master device provides synchronization signals for other devices in the wireless system. This master device may be linked to other, wired parts of the system or to other timers for the purpose of establishing the synchronization signals.

The master device transmits a periodic synchronization signal. The other devices will adjust their individual ON/OFF, active/inactive, times to match the expected synchronizing signal.

In a system in accordance with the invention, the devices learn the timing of a periodic synchronization signal and then go to a "sleep or OFF" state between synchronizing signals. For example, a synchronization signal could have a period of 10 seconds. All devices that have

learned the 10 second period, go to a "wake or ON" state just prior to the expected arrival of the next synchronization signal.

In an exemplary embodiment, all devices have their receivers turned ON and receive incoming signals evaluating the content of information in the signal and responding appropriately. If the signal is requesting information (alarm, trouble, output state, etc.) to be transmitted by some or all of the devices, then the appropriate devices will respond as programmed to activate their transmitters and transmit such information which is then received by some or all devices in the system.

The advantages of such synchronization include 1) the devices can operate both transmitters and receivers while maintaining a long battery life, 2) the devices can parallel process information regarding system conditions (alarms, troubles, output states, input states, etc.) from other devices, 3) there are no communication collisions that corrupt data or interfere with communication, and 4) the devices can be programmed or have their programs changed through a wireless link.

The devices can include smoke, gas, temperature, light, beam, etc. types of detectors. Other devices could include control units of various types such as horns sounders, alarm indicating lights, motion controls, relay or solenoid control units and the like without limitation.

Wireless transmission can be effected using RF frequencies, sonic, ultrasonic, optical frequencies such as infrared or higher frequencies all without limitation. Modulation type is not a limitation of the invention, nor are the nature and character of the synchronization signals. Exemplary types of modulation include spread spectrum, multiple frequencies, FM modulation, AM modulation, or ON/OFF keying.

Different communication configurations of a system can be used without limitation. In a preferred system, the devices have their receiver and transmitters tuned to the same frequencies (can be spread spectrum). This means that the devices will receive any signals that are transmitted on that frequency including their own transmissions. Alternately reception and transmission can be at different frequencies.

The devices are programmed to become active just before the expected time of arrival of the synchronization signal and to stay active until it is received. The respective device(s) will then prepare to transmit their information to transmit based upon the information in the synchronization signal and/or their states or conditions. All devices incorporate a high accuracy

internal clock and have a synchronized internal time base. At a specific preset time, they will begin their transmissions.

For a new device that is installed in the respective system or if a device does not properly establish the timing for the synchronization signal, the respective device will continually maintain its receiver ON until it receives the expected synchronization signal. Then it will establish the timing to go into an active/inactive cycle that matches the synchronization timing. If it later awakens, becomes active and finds no synchronization signal, it will stay ON and wait for a synchronization signal so as to readjust its timing for the active/inactive cycle.

If the controller/sender of the synchronization signal has failed, then another device can take over that role and become the sender of synchronization signals for the system. The selection of the sender can be by preprogramming or by any other method.

In the preprogrammed method, the absence of the synchronization signal for a predetermined period of time will activate the next-in-line controller. In one of many other methods, each device selects a random priority message. All devices in the system arbitrate the priority of this message and select a new device, which becomes the controller/sender of the synchronization signals.

A signal or bit arbitration method can be incorporated to prevent devices from transmitting conflicting digital information. For example, a device uses ON/OFF keying wherein ON is represented by transmitting the frequency and OFF is not transmitting the frequency. The devices all start their messages at the same time and continually monitor their receivers to check that the received signal is the same as their transmitted signal (receiving a 0 bit when transmitting a 0 bit, receiving a 1 bit when transmitting a 1 bit).

Because transmitting a frequency has priority over not transmitting a frequency, the devices monitor their own transmissions as well as the transmissions of the other devices. If they receive a 1 bit when they are trying to send a 0 bit, then they know that another device has a higher priority message than their own message and they stop transmitting until the other message is completed. After the other message is completed, they again try to send their own message that continues to be bit arbitrated with all other messages. Eventually, the message of each device will be completed in order of the priority of the messages in the RF system.

Another method of signal arbitration is to have each device start its respective message with a time duration priority signal that is compared by that device with all other devices in the

system. The longer the time duration, of the priority signal, the higher the priority of the message. When it is time for the devices to transmit information, each transmits a continuous signal with a time length preprogrammed according to the priority.

Each device is monitoring its own receiver which receives both its own transmissions and the transmissions of all other devices. A device stops sending its priority signal and the receiver is still receiving a priority signal from another device, then that device knows that another device has a higher priority and will wait until the other device completes its message before retrying to send its own message.

The restart of the next message time is referenced to the end of the previous message so all remaining devices that need to transmit information remain coordinated and synchronized. This arbitration can use a single signal or a series of signals to establish this priority without departing from the spirit and scope of this arbitration method. Other arbitration methods, without limitation, can be used with the devices to prevent the collision of messages within this synchronized system.

Fig. 1 illustrates an exemplary system 10 with a controller/sender of synchronization signals 12 and a plurality 14 of w wireless devices 14-1....14-w that can receive and transmit signals between all devices as well as the controller 12. It will be understood that neither the device type nor the number of devices is a limitation of the invention.

The members of the plurality 14 are in wireless communication with one another as described in more detail subsequently. Each of the members of the plurality 14 incorporates, for example, an RF antenna 16-1....w which is coupled to a transceiver in the respective unit, best seen in Fig. 1A, to provide bi-directional communication between the members of the plurality 14 as well as the synchronizing control unit 12. It will be understood that the details of such communications are not limitations of the present invention. Additionally, whether or not the members 14 are in uni-directional communication with the synchronizing circuitry 12 or bi-directional communication is not a limitation of the present invention.

Unit 12 can be a stand alone unit or, can be incorporated into and part of more extensive alarm control circuitry 20. Circuitry 20 can be in communication with a plurality of ambient condition detectors/control units 22, all without limitation. Neither the details nor the number of the detectors/control units 22 are limitations of the present invention.

Relative to synchronizing/control circuit 12, it will be understood that synchronizing transmissions therefrom can be on the same or a different frequency or frequency band than the devices 14 receive and transmit on.

Fig. 1A is a block diagram illustrating exemplary details of a representative member 14-i of the plurality 14. The member 14-i can incorporate a transceiver 30 which is coupled to an RF antenna 16-i, as well as control circuitry 32.

The control circuitry 32 can in turn receive signals from an optional ambient condition sensor or sensors 34a or other input devices. Alternately or in addition thereto, control circuitry 34 can communicate with optional output circuitry 34b which could include relays, solenoids, sounders, lights, enunciators, strobes or the like, all without limitation.

The unit 14-I receives electrical energy from an internal source 36. Source 36 can be implemented as a self-contained battery where the unit 14-I is carried within housing 38 and is mountable to a selected surface as appropriate for its function or functions as would be understood by those of skill in the art. Alternately, energy source 36 can be coupled to an exterior source of energy, such as utility supplied power if desired.

As described above, and relative to Fig. 2 subsequently, control circuitry 32 appropriately couples energy to transceiver 30 in anticipation of receiving synchronization signals from unit 12. It will be understood that if desired, only the receiver portion of transceiver 30 need be energized in anticipation of receipt of the synchronization signals.

Fig. 2 illustrates activation of the devices 14 relative to the synchronization signals and transmissions which in this example are simply ON or OFF. In time period A, the device 14-n wakes up or becomes active just prior to the synchronization signal being sent. It receives the synchronization signals and determines that it is to respond with a device 14-n transmission based upon its internal state condition. Other devices were not to respond based upon their internal state conditions.

In time period B, the device 14-n wakes up just prior to the synchronization signal and determines that neither it nor any other detector have state conditions for it to respond. Time period B will be representative of the vast majority of times since state conditions in the devices change very infrequently.

During time period B, the receiver of each device is ON for only a little longer than 2 milliseconds every 10 seconds, yielding an average power consumption RECEIVER-ON/5,000.

If the RECEIVER-ON current draw is 5mA, then the average current draw related to the receiver would be 1 micro-amp.

In time period C, the devices 14 become active just prior to the expected arrival of the synchronization signals and various detectors determine that they have state conditions for multiple device responses. In this case, device 14-n has the highest priority and transmits first, followed by the other devices arbitrating to their transmission times.

While any device is transmitting, all the devices keep their receivers ON to receive any and all messages. This enables all devices to integrate the state conditions of other detectors with their own state to determine the response of the device (sound horn, turn on relay, etc.). For example, if the devices turn on a relay to active a sprinkler system, they could require that other grouped devices or detectors also have a state condition that matches their own state condition.

Fig. 3 illustrates another method of arbitration of the devices. Each transmits at a predetermined time after the RF synchronization signal is received. The devices can select the predetermined time based upon the information that they are going to transmit in combination with a random number selection or their unique address ID.

For example, in Bit 7 of Byte 1 time slot, devices 1, 2, and 3 are all going to transmit a data=1 bit. Each therefore will make a transmission during the time slot for Bit 7 of Byte 1 but at different random times or different address IDs so they do not overlap in time. In Bit 6 of Byte 1, device 1 is sending data=0 (no transmission) and devices 2 and 3 are transmitting data=1. Device 1 notes that another device transmitted a data=1 that has a higher priority during Bit 6 of Byte 1 time and thus arbitrates itself off the communication until the message by other devices is completed.

The above process continues until only one device is remaining and then that remaining device transmits its message without interference from other devices. Finally, the other devices transmit their message in order with their learned priorities from the arbitration process. Alternately the above process could be carried out without the devices learning their order from the prior message transmitting process.

Figure 4 illustrates a method using different frequency modulations to discriminate the different devices. Each device is capable of receiving and decoding the frequency modulations to identify other devices simultaneously. The devices will arbitrate themselves according to the priority of the information being transmitted.

From the foregoing, it will be observed that numerous variations and modifications may be effected without departing from the spirit and scope of the invention. It is to be understood that no limitation with respect to the specific apparatus illustrated herein is intended or should be inferred. It is, of course, intended to cover by the appended claims all such modifications as fall within the scope of the claims.